Chapter 8 Freshwaters

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8.1 Introduction

The aim of this chapter is to provide a summary of the current quality of pond and headwater stream habitat in Wales through the results of a field survey, and identify the influence of Glastir on their condition. We also include an analysis of long term national trends, and of the influence of past agri-environment schemes (Tir Gofal) on headwater stream habitats.

8.2 Headwater streams

8.2.1 Introduction

Headwater streams are an important part of the river network, they typically account for most of river length in catchments (typically 70 to 80 % across the EU). They occur across a wide range of geological, biogeographic and riparian settings, and display a wide range of temperatures, substrates, hydrological regimes and water chemistry which shape their biodiversity (Meyer et al, 2007). They route precipitation to downstream water bodies, supporting these larger ecosystems as well as key societal services such as potable water, water for industry and agriculture. The biota of headwater streams makes a significant contribution to biodiversity at a national level with many plants and animals geographically restricted to these characteristic habitats, while some use these habitats seasonally or intermittently. EU legislation aims to protect headwater streams through the Water Framework Directive (European Commission, 2000), where all water bodies are expected to reach good or high ecological status, the Habitats Directive (European Commission, 1992), and the UK Biodiversity Action Plan where headwater streams are considered ‘priority habitat’ and hence a focus for conservation. Headwaters also harbour species protected under the Wildlife and Countryside Act 1981 and its amendments (e.g. white clawed crayfish), nationally important species of fish such as Atlantic salmon, brook lamprey and bullhead, and can support protected species of mammals and birds (e.g. otters, kingfishers).

Headwater streams are upstream of most point sources of pollution such as industrial discharges, sewage effluent and water abstraction. This means that they are not routinely monitored by the agencies responsible for environmental quality assessments. However headwater streams are small water bodies, strongly connected with the adjacent landscape (Richardson and Danehy, 2007) and are vulnerable to non-point sources of pollution, including diffuse discharges of nutrients and sediments for agriculture and forestry, and habitat loss/modification. Upland headwater streams are also considered to be particularly vulnerable to atmospheric deposition and climate change. In some areas, headwater streams can be affected by water abstraction, and by habitat loss due to land intensification or urbanisation. Conversely, headwaters are typically less impacted by species invasions because of limitations on dispersal, so provide important refugia for native species. Some upland headwaters are also free of fish and provide rare habitats for invertebrates where predation pressure is low. More generally, headwater streams are recognised as refugia for species that have been extirpated downstream (Saunders et al. 2002).

Agricultural practices such as livestock grazing and tilling can lead to soil erosion and run-off of fine sediments, nutrients and pesticides into headwater streams. This has direct effects on the biota and habitat integrity, for example decreasing biodiversity and causing a replacement of sensitive fauna by pollution tolerant types. Cumulative impacts across headwaters are reflected further down the river network, decreasing the water quality of larger waterbodies, with negative consequences for their biota, and for ecosystem services such as the provision of clean water for human consumption, fish farming and recreation. Hence it is not surprising that water quality is a key target of many agri-environment schemes, including Glastir, with options that aim to reduce run off and increase ecological buffering along streams and rivers.

Headwater streams are currently under-represented in NRW monitoring programmes which GMEP is intended to fill. The NRW target ultimately is all surface waters to reach good ecological status as required by EU legislation. However, the size and vast numbers of headwaters means that it may be a strict WFD approach may not be practical. As headwater streams also need to be reported under the habitats directive as they are 'priority habitats' is may be more appropriate to report impacts results for headwaters under Priority habitats rather than the WFD compliance. In this report, we describe ecological quality of headwater streams but do not translate this to WFD classification. GMEP and NRW will collaborate on further analyses so that GMEP results can be expressed in a way that is consistent with WFD requirements and approaches, because the data field collection methods that were used in GMEP are consistent with the methods used in WFD assessments. Impact of Glastir on larger rivers will be explored using a modelling approach to quantify change in the contribution of agriculture to nutrient inflow in Year 4 however formal WFD assessment will rely on NRW ecological assessments. There is no benefit of GMEP repeating this assessment.

8.3 Freshwater highlights from Year 2

One headwater stream and pond were surveyed when they occurred in the GMEP 1km survey squares in 2013. Due to the time required for identifying the many invertebrate and diatom samples. The 2014 is not yet ready for reporting. Selected highlights of the results include:

8.3.1 Streams

- 57% of GMEP 1km survey squares had at least one headwater stream
- Lowland sites demonstrated nutrient enrichment vs upland sites
- 85% of sites had phosphorous concentrations consistent with supporting good ecological quality, sites that did not achieve this were all in lowland bar one.
- 53% of sites had nitrogen concentrations that exceeded the range associated with unimpacted European rivers. No site exceeded the drinking water standard for the UK.
- 91% of sites were modified in some ways, with 32% of sites displaying high levels of modification.
- Lowland sites demonstrated higher levels of habitat modification
- Macroinvertebrate indicators indicated 62% of sites had macroinvertebrate communities consistent with good ecological quality.The principal drivers of macroinvertebrate communities were biogeographic (altitude, alkalinity, conductivity) but human habitat modification was also a driving factor
- Diatoms were more responsive to the altitude gradient, with better ecological quality in uplands (expected as diatom indicators principally respond to nutrient status) but higher diversity in lowlands, as expected.
- The principal Diatom score was less conservative, indicating 91% of sites had diatom communities deemed of good ecological quality
- Macrophyte indicators reflected the higher nutrient status of lowlands. Most sites showed intermediate levels of enrichment, only 1 lowland site could be diagnosed with clear eutrophication impacts and 12 sites (9 of which in uplands) could be diagnosed as unlikely to be impacted by eutrophication or organic pollution

- Long term trends using NRW data indicated an improvement in ecological quality of streams over the last two decades, linked to improvements in water quality. This is consistent with the UK wide pattern.
- There was a trend (not significant at present but likely to become so as more baseline samples are taken) of higher quality headwater streams on land within the Glastir scheme which needs to be taken into consideration in future analysis of the benefits of Glastir.
- No significant legacy effect of previous agri-environment schemes was detected though there was a trend for a positive effect on ecological quality and sample size was low as this represents only Year 1 of the full 4 year GMEP sampling period.
- Impacts of Glastir on nutrient enrichment levels in freshwaters more generally will be quantified using a modelling work as described in the GMEP Year 1 report.

8.3.2 Ponds

- 48% of GMEP 1km survey squares had at least one pond
- There was a trend for nutrient enrichment in lowlands which was not significant
- Macrophyte indicators reflected the nutrient conditions, though more uncommon species were found in uplands
- The main drivers of the macroinvertebrate community were natural (alkalinity, altitude) but phosphorous concentrations were also an important driver and are likely to be influenced by human activity
- Only 8% of ponds were judged to be of good ecological quality, most others were of moderate ecological quality
- As for streams, no significant difference between pond condition in and out of scheme was detected but there was a trend for a positive effect of Glastir on ecological condition which will need to be taken into consideration when the impact of Glastir is assessed. Further survey data will clarify this.

8.4 Freshwater Methods

GMEP 1km survey squares are sampled for 1 headwater stream and 1 pond when present. The techniques deployed in headwater streams are recognised biomonitoring techniques as adopted at the UK and EU level, thus our results can be compared to NRW/EA monitoring data,. In ponds, the techniques most widely used, and recommended by the Freshwater Habitats Trust, were used (there is no recognised standard technique at either the UK or EU level) to monitor macroinvertebrates, macrophytes and habitats. These techniques allow us to determine chemical water quality as well as ecological quality.

In brief, the physical, biological and chemical condition of headwater streams are recorded to assess the impact of Glastir options on water quality. To be eligible for inclusion within the GMEP survey streams had to be 1st or 2nd order, at least 500m long, with most of its catchment in the GMEP 1km survey square. Where GMEP 1km survey squares had more than one stream suitable, the most representative of the square (based on length of stream in the actual square) was selected. Water chemistry, diatom community, macroinvertebrate community, aquatic plant community, hydromorphological and physical characteristics of the watercourse (River Habitat Survey Amended) were recorded. The length of the headwater stream sampling site is 500m of watercourse which defines the limits of the River Habitat Survey area. A 100m aquatic plant survey, 10m macroinvertebrate and diatom survey and water chemistry sampling points were all nested within this length centred on the mid-point. The River Habitat Survey is a description of over 150 potential river characteristics recorded on a one 500m stretch of river in each 1km^2 such a pools and riffles, overhanging trees and physical structures. The macrophyte survey recorded species presence and

abundance over a 100m length to give a mean trophic rank index of water quality. Five diatom samples were collected and bulked from the central 10m reach –diatoms for assessing ecological quality. Timed searches for macroinvertebrates across a 10-15m reach were undertaken using standard RIVPACS methodology. Environmental variables such as stream width, depth; surface velocity: substrate; algae; plants; street lighting; sketch + photo; GPS were recorded with the 10m reach. The conductivity and pH of the water was recorded on-site; and an additional water sample taken and filtered on site before being sent for alkalinity, soluble reactive phosphorus and total oxidisable nitrogen analysis the in laboratory.
For more information, please see GMEP year 1 report. (Emmett et al. 2014)

8.5 GMEP: what is the condition of headwater streams?

Headwater streams were monitored in 60 x GMEP 1km survey square across Wales in 2013 (Year 1 of the survey), with 1 stream from each square selected for detailed surveying.
Of the 60 GMEP 1km survey squares, 57% (34) had at least one headwater stream. Of these 34 streams, 17 (50%) were situated in lowland (< 200m) and the other 50% in upland (>200m).

8.5.1 Stream habitat

River Habitat Surveys indicated significant human modification of stream habitats (Table 8.5.6.1). The habitat modification score (HMS) average was 754 (±172) corresponding to an overall Habitat Modification Class of 4 out of 5 possible classes were 5 is the most modified. The habitat quality assessment of natural structural diversity (HQA) average was 53.7 (±2), a value in line with expectations for headwater streams but higher than that recorded for Welsh streams in the 1998 and 2007 Countryside surveys (42.3 and 49.2 respectively). The HQA and HMS were negatively correlated ($r = -0.541$, $p < 0.001$) demonstrating that natural habitat quality decreased with the extent of human modification. However this correlation was driven by the lowland sites (-0.712, $p = 0.001$) as no such pattern occurred in the highlands. Analysis of HMS and HQA indicated a strong negative correlation of HMS with altitude (-0.427, $p = 0.01$), which ranged from 7 m to 537 m, so that the HMS was lower in upland areas (Figure 8.5.6.1) however the HQA was not correlated to altitude, and neither were correlated to distance from source, which ranged from 0.2 to 4 km.

8.5.2 Water chemistry

Analysis of water chemistry samples (Table 8.5.6.2) indicated strong differences between uplands and lowlands in alkalinity and conductivity, with higher values in lowland, which reflects natural biogeochemical processes. The stream water pH did not differ significantly between lowland and upland, and was generally above the recommended threshold of 5.95 (WFD UK TAG, 2012) higher. Only 5 sites fell below this pH(4 upland sites, 1 lowland site). Nutrients displayed significant differences in their concentrations between upland and lowland (Figure 8.5.6.2). Nitrogen expressed as Total Dissolved Nitrogen (TDN) and phosphorus expressed as phosphate (PO_4P) were an order of magnitude higher in the lowlands. Cardoso et al (2001) reviewed TDN concentration for pristine European rivers (and excluding larger rivers) and observed that they lied in the range 0.2 – 1 mg/l. In our survey, despite their headwater status, 52.9% of sites had TDN concentrations above this range, representing 18 sites, 14 of which were in the lowlands. No site exceeded current drinking water standards for nitrogen (10.9 mg/l). TDN was not correlated to either the HMS and HQA or distance from source. We calculated phosphorous concentrations expected from unimpacted sites using a model based on altitude and alkalinity, which reflect concentrations if the ecosystem is undisturbed (WFD UK TAG, 2014), plotted these values against observed values (Figure 8.5.6.3) and derived a ratio of observed to expected values, which also differed between upland and lowland (Table 8.5.6.2). In upland areas this ratio was below 1, i.e. observed values did not exceed predicted reference values. However in the lowland it was clear that observed measurements exceeded reference P values in approximately a third of the sites.

8.5.3 Macroinvertebrates

Invertebrate communities were assessed at each stream site using a standard biomonitoring technique (the RIvPACS approach; Wright et al, 1993). A range of indicators based on the invertebrate community were calculated (Table 8.5.6.3). Habitat variables recorded in the field were used in the RIvPACS model to predict some of these indicators at the sites, if the site was unimpacted by human stressors (reference condition). Observed values were then compared to the predicted values of the RIVPACS model as a ratio.

The Average Score per Taxon (ASPT) and Number of Scoring Taxa (Ntaxa) are related to the Biological Monitoring Working Party score (BMWP, 1978, Armitage et al, 1983), and are indicators designed to detect eutrophication, but are also considered indicators of general degradation. Higher values indicate higher ecological quality. The ASPT describes the sensitivity of species to water quality and was higher (though not significantly so) in upland areas which are known to be associated with sensitive taxa. Ntaxa describes the number of water quality sensitive taxa used in the assessment, and this was significantly higher in the lowland areas, principally because lowland areas sit in a wider species pool.

We also calculated an ASPT based on the Acid Water Indicator Community (AWIC, Davy-Bowker et al, 2005) score, an indicator of acid conditions. Higher values indicate less acid conditions, but the score doesn't differentiate between naturally acid conditions and anthropogenic acidification. The score was significantly higher in lowland areas, in line with the trend for higher pH and conductivity. The Proportion of Sensitive Invertebrates (PSI, Extence et al, 2013) is an indicator of fine sediment deposition, where higher values, expressed as percentages, indicate better ecological quality. Though values were highest in the upland areas, the difference with lowlands was not significant. Mean values for both upland and lowland placed the sites in the 'slightly sedimented' band (the second highest).

The Lotic Invertebrate Flow Evaluation (LIFE, Extence et al, 1999) score is an indicator of flow conditions, where higher values indicate better flow conditions. There was no significant difference between lowland and upland.

The Community Conservation Index (CCI, Chadd et al, 2004) is a measure of the conservation value of the invertebrate community, it ranges from 0 to 40 where 40 is the highest conservation value. There was no significant difference between upland and lowland. Mean values in both areas (~ 11) indicated an invertebrate community of '*fairly high conservation value*' driven by high taxon richness and species of restricted distribution.

We calculated two species richness indices: Margalef richness (M, Margalef, 1958) is a measure of richness corrected for the number of individuals (as the number of species increases passively with the number of individuals) and true richness (n) i.e. the number of recorded taxa (principally at species level though some taxa were recorded at higher levels of taxonomic organisation). Neither index differed significantly between upland and lowland though there were marginally more species in lowland areas.

We calculated the expected values of ASPT and Ntaxa (using the RIvPACS model, which predicts the reference state invertebrate community of a stream based on a range of environmental variables. We then calculated the ratio of observed to expected values (Table 8.5.6.4), or ecological quality ratio, where 1 or above indicates a community under reference conditions (near unimpacted by

human activity). The mean O/E ASPT was high (above 0.86 indicating good ecological quality). Though lowlands and uplands did not differ significantly, the ASPT was higher in uplands, near 1,. The mean O/E Ntaxa also indicated good ecological quality , but lowland sites had a higher mean.
We used the occurrence and abundance of macroinvertebrates in the samples to produce an ordination using a technique called canonical correlation analysis (CCA). This technique attempts to explain patterns in variation in the community using selected environmental variables. It has the advantage of producing a graphical representation of patterns. We used a range of variables and tested their contribution to the CCA model using permutation tests. This indicated that TDN, PO4P, distance from source, altitude of source, water pH and the HQA score did not contribute significantly to the model, but retained water conductivity, the HMS score, water alkalinity and altitude as significant explanatory variables. The model was then plotted in an ordination, where the distance between samples is a measure of their ecological distance, and where the graph axes represent a combination of the driving variables, which are plotted as vectors, the length of which is an indicator of the influence of the variable (Figure 8.5.6.4). The graph shows that the HMS is a strong driver, especially in lowland sites. Alkalinity and conductivity also have some influence, though these are likely to act as proxies for geology and location. There is a strong effect of altitude, which differentiates upland sites more strongly than their water chemistry. Though correlation is not causation, this analysis indicated that important determinants of invertebrate community structure were in line with the geography of the land, and habitat modification is the principal driving human influence rather than water chemistry.

8.5.4 Macrophytes

Macrophyte communities were assessed at each site using the Mean Trophic Rank (MTR, Holmes et al. 1999), an indicator of eutrophication. This approach yields an overall MTR score and also a number of scoring plants and a number of high scoring plants, where higher values represent higher ecological quality (Table 8.5.6.5). Uplands and lowland sites differed significantly in their mean MTR score. The mean for upland sites indicated that eutrophication was very unlikely. However the lowland mean indicated a potential risk of eutrophication, consistent with the higher nutrient concentrations and signal from the macroinvertebrate scores. Only 1 (lowland) site had an MTR below 25, a recognised threshold at which sites are degraded by either eutrophication or organic pollution. Another 12 sites had an MTR > 65 so were unlikely to be impacted by eutrophication and organic pollution (9 upland, 3 lowland). The remaining sites had intermediate values for which a clear diagnosis is not possible, where some level of organic pollution was possible.

8.5.5 Diatoms

Diatom communities were assessed at each site (Table 8.5.6.6) using a standard biomonitoring technique DARLEQ (Diatoms for Assessing River and Lake Ecological Quality) which yields a suite of ecological quality scores (Kelly and Whitton, 1995; Kelly et al. 2008).
The Trophic Diatom Index (TDI) is an indicator of eutrophication ranging from 0 to 100 where low scores indicate better ecological conditions. The TDI showed a significant difference between uplands and lowlands, and the mean values was higher in the lowland sites. We also calculated the expected value of the TDI in the absence of human influence (reference condition) using the DARLEQ predictive model, based on site environmental variables. We calculated the observed to expected ratio, where values of 1 or above correspond to the expectations of reference conditions. The mean O/E ratio of the TDI was highest in the uplands sites, where it exceeded one. The mean was considerably lower in lowland sites, indicating greater eutrophication pressure.
The Diatom Acidification Metric (DAM, Juggins and Kelly, 2013) was developed to assess the impact of acidification, though it is not possible to distinguish between naturally acid and acidified sites in this survey. Higher values indicate less acidic conditions, as calculated from benthic diatom assemblages. The mean DAM was significantly higher in lowland sites, in line with water chemistry

results and the macroinvertebrate acidification indicator (AWIC). The mean DAM in uplands corresponded to the ‘slightly acidic’ range, and the mean for lowland sites corresponded to the circumneutral range. In total 4 sites were considered to be very acid, 3 sites were alkaline, 11 were slightly acidic and the rest circumneutral.

The percentage of motile diatoms is an indicator of fine sediment deposition, it increases with increased siltation. The mean value was higher in lowland sites, but differences between upland and lowland were not significantly different.

8.5.6 Ecological quality

We classified the sites based on their putative ecological quality using observed to expected ratios of the indicators only for indicators with established predictive models and classification thresholds. This is not a WFD assessment because this would integrate all elements to produce a final site classification. We do not present a WFD classification, nor assign the sites to an overall status. Each indicator is treated separately. In further years we will integrate all monitored elements into an assessment protocol that be compatible with WFD assessments.

The headwater sites were classified according to their habitat modification score using established thresholds into five modification classes. (Near natural, predominantly unmodified, obviously modified significantly modified, severely modified). Only 8.8% of sites were deemed near natural with a further 38.2% classified as predominantly unmodified, while 52.9% of sites fell in the top three modification categories. Moreover 32.3 % of the sites were either severely or significantly modified, and these modification classes are general accepted as being inconsistent with supporting high ecological quality (Figure 8.5.6.5).

Phosphorous concentrations were compared to predicted modelled values (WFD UK TAG, 2014) , and the model also yields thresholds for O/E ratios to assign sites into 5 bands (bad, poor, moderate, good , high) which are intended to reflect the ecological quality that the concentrations would be able to support (though this model/tool is used in WFD assessments, we simply use it here to classify sites according to their phosphorous concentrations). We found that 85.2% of sites had phosphorous concentrations consistent with supporting high/good ecological quality, only 2 sites had phosphorous concentrations that would be expected to be associated with bad/poor ecological quality.

We classified the headwater sites based on their diatom communities using the ratio of observed TDI to that predicted by the DARLEQ tool. We used this ratio to classify sites into 5 equal bands (TDI of 0.2, 0.4, 0.6, 0.8) corresponding as above to 5 putative ecological quality classes. This gave an overwhelmingly positive snapshot of ecological quality, with 90.9% of sites falling in the top two categories (high or good), only 3 sites were deemed of moderate ecological quality based on diatoms, and no sites fell in the bottom two categories (poor/bad).

We used a similar process for macroinvertebrates ASPT and NTAXA, using the ratio of observed values to that predicted by the RIvPACS model. For these scores thresholds are established to classify the sites into 5 putative ecological quality classes as above.(ASPT: 0.63,0.75,0.86,0.97 Ntaxa: 0.47, 0.57, 0.71, 0.85). THE ASPT indicated 88.2% of sites fell in the top two ecological quality categories, while Ntaxa indicated this for 64.7% of the sites. Considering both scores together so as to classify the sites based on the lower of the two metrics, 61.7% of sites fell in the top two ecological quality bands.

		Mean	± SE	Min	Max
Habitat Modification Score	Overall	762	177	0	4110
	Lowland	1035	292	0	4110
	Upland	490	186	0	2925
Habitat Quality Assessment	Overall	53.71	2.2	31	80
	Lowland	52.53	3.75	31	80
	Upland	54.88	2.38	35	70

Table 8.5.6.1 *River habitat survey results for 34 headwater streams surveyed in GMEP 2013.*

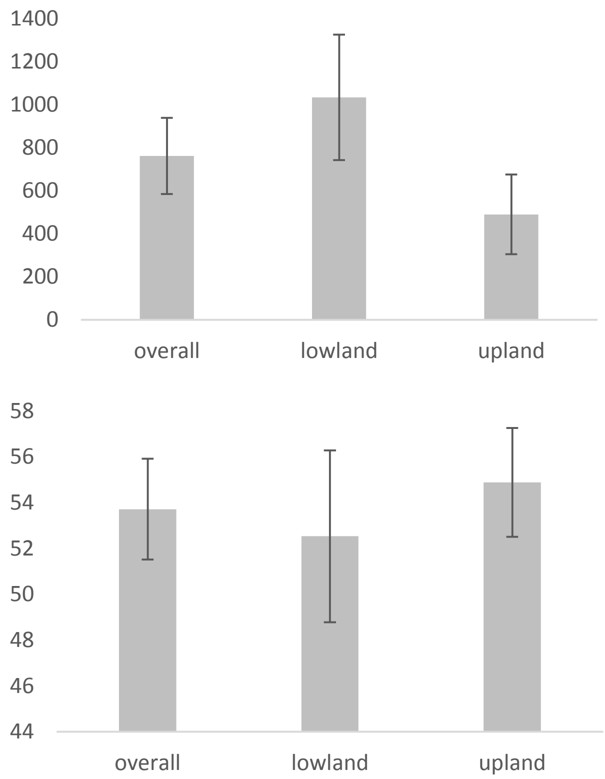

Figure 8.5.6.1 *River habitat survey results. Mean HMS (TOP) and HQA (Bottom) ± 1SE.*

		Mean	SE	Min	Max
Alkalinity (mg/L)	Overall	48.38	9.03	0.10	218.00
	Lowland *	72.30	14.90	0.90	218.00
	Upland	24.48	6.64	0.10	74.60
PO4-P (mg/L)	Overall	0.020	0.007	0.001	0.179
	Lowland *	0.037	0.012	0.001	0.179
	Upland	0.005	0.001	0.001	0.018
PO4-P (O/E)	Overall	1.52	0.40	0.06	9.88
	Lowland *	2.35	0.76	0.06	9.88
	Upland	0.73	0.19	0.12	2.34
TDN (ppm)	Overall	1.40	0.24	0.07	5.56
	Lowland *	2.16	0.38	0.07	5.56
	Upland	0.69	0.16	0.15	2.88
pH	Overall	6.58	0.12	5.31	7.81
	Lowland	6.72	0.18	5.31	7.81
	Upland	6.45	0.15	5.60	7.68
Conductivity ($\mu S.cm^{-1}$)	Overall	188.00	23.20	22.00	526.00
	Lowland *	266.00	33.10	62.00	526.00
	Upland	110.00	18.90	22.00	247.00

Table 8.5.6.2 *Water chemistry results for 34 headwater streams surveyed in GMEP 2013. Asterisks denote significant higher values*

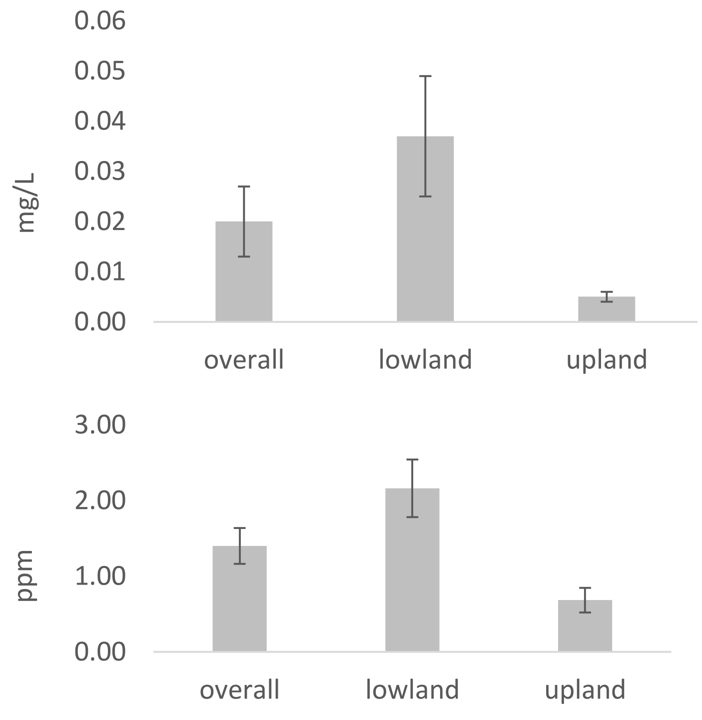

Figure 8.5.6.2 *Concentration of PO4P (Top, mg/L) and TDN (Bottom, ppm) in stream water samples*

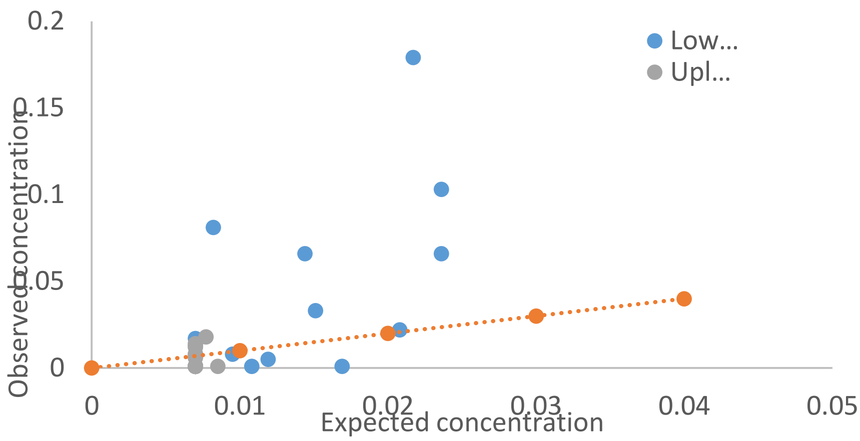

Figure 8.5.6.3 *Observed PO4P concentrations plotted against expected values (blue points) with 1:1 line plotted in orange (where observed equals predicted)*

		Mean	SE	Min	Max
ASPT (BMWP) (Eutrophication/general degradation)	Overall	5.84	0.13	4.00	7.00
	Lowland (<200m)	5.60	0.19	4.00	6.73
	Upland (>200m)	6.01	0.14	4.86	7.00
Ntaxa (BMWP) (Eutrophication/general degradation)	Overall	18.56	0.94	7.00	28.00
	Lowland (<200m) *	20.47	1.05	11.00	26.00
	Upland (>200m)	16.65	1.44	7.00	28.00
ASPT (AWIC) (Acidification)	Overall	4.55	0.09	3.25	5.67
	Lowland (<200m) *	4.88	0.10	4.13	5.67
	Upland (>200m)	4.23	0.11	3.25	4.92
PSI (Sedimentation)	Overall	67.06	3.62	14.29	100.00
	Lowland (<200m)	60.45	5.35	14.29	80.00
	Upland (>200m)	73.66	4.48	38.46	100.00
LIFE (Water flow)	Overall	7.23	0.13	5.13	9.09
	Lowland (<200m)	7.08	0.20	5.13	8.10
	Upland (>200m)	7.38	0.17	6.09	9.09
CCI (conservation value)	Overall	11.63	0.75	4.15	21.00
	Lowland (<200m)	11.93	1.17	4.15	21.00
	Upland (>200m)	11.33	0.95	4.71	18.20
Richness (Margalef) (Biodiversity)	Overall	5.28	0.27	1.82	8.69
	Lowland (<200m)	5.61	0.32	3.17	7.94
	Upland (>200m)	4.96	0.43	1.82	8.69
Richness (Biodiversity)	Overall	35.62	2.35	7	60
	Lowland (<200m) *	40.65	2.86	22	60
	Upland (>200m)	30.59	3.39	7	59

Table 8.5.6.3 *Macroinvertebrate indicators of ecological quality. Asterisks indicate where one altitude category is significantly higher than the other.*

		Mean	SE	Min	Max
O/E ASPT (BMWP)	Overall	0.96	0.02	0.70	1.16
	Lowland (<200m)	0.93	0.03	0.70	1.08
	Upland (>200m)	0.99	0.02	0.77	1.16
O/E Ntaxa (BMWP)	Overall	0.83	0.05	0.30	1.42
	Lowland (<200m)	0.88	0.06	0.30	1.31
	Upland (>200m)	0.78	0.07	0.31	1.42

Table 8.5.6.4 *Observed vs Expected ratio (O/E) of the two main macroinvertebrate indicators*

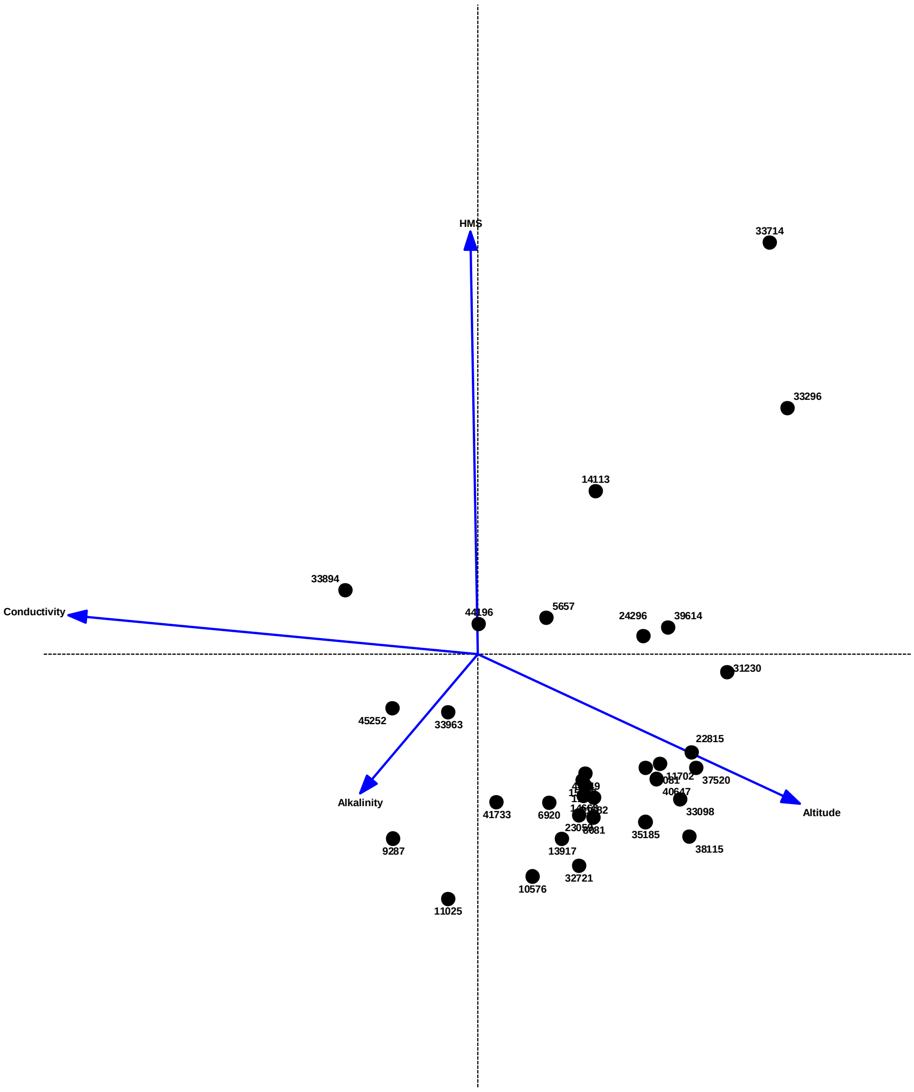

Figure 8.5.6.4 *CCA graph of stream macroinvertebrate community data with retained driving variables.*

		Mean	SE	Min	Max
MTR score	Overall	63.63	4.06	24.55	100.00
	Lowland (<200m)	49.07	4.38	24.55	70.00
	Upland (>200m) *	78.19	3.78	60.00	100.00
Ntaxa (MTR)	Overall	2.62	0.42	0.00	8.00
	Lowland (<200m)	2.33	0.48	0.00	6.00
	Upland (>200m)	3.00	0.76	0.00	8.00
Nhigh (MTR)	Overall	1.50	0.26	0.00	4.00
	Lowland (<200m)	1.33	0.29	0.00	4.00
	Upland (>200m)	1.73	0.47	0.00	4.00

Table 8.5.6.5 *Macrophyte indicators of ecological quality. Asterisks indicate where one altitude category is significantly higher than the other.*

		Mean	SE	Min	Max
TDI	Overall	29.41	3.60	0.16	64.62
	Lowland (<200m) *	42.09	4.47	11.09	64.62
	Upland (>200m)	17.48	3.80	0.16	51.72
O/E TDI	Overall	0.92	0.03	0.53	1.28
	Lowland (<200m)	0.82	0.05	0.53	1.28
	Upland (>200m) *	1.01	0.03	0.67	0.16
% Motile	Overall	16.68	2.62	0.32	53.72
	Lowland (<200m)	21.47	4.26	1.93	53.72
	Upland (>200m)	12.17	2.84	0.32	35.95
DAM	Overall	46.64	4.20	3.75	92.32
	Lowland (<200m) *	56.69	5.87	6.07	91.94
	Upland (>200m)	37.17	5.16	3.75	92.32
Ntaxa (TDI)	Overall	26.91	1.69	10.00	52.00
	Lowland (<200m) *	30.56	2.71	10.00	52.00
	Upland (>200m)	23.47	1.76	10.00	35.00

Table 8.5.6.6 *Diatom indicators of ecological quality. Asterisks indicate where one altitude category is significantly higher than the other.*

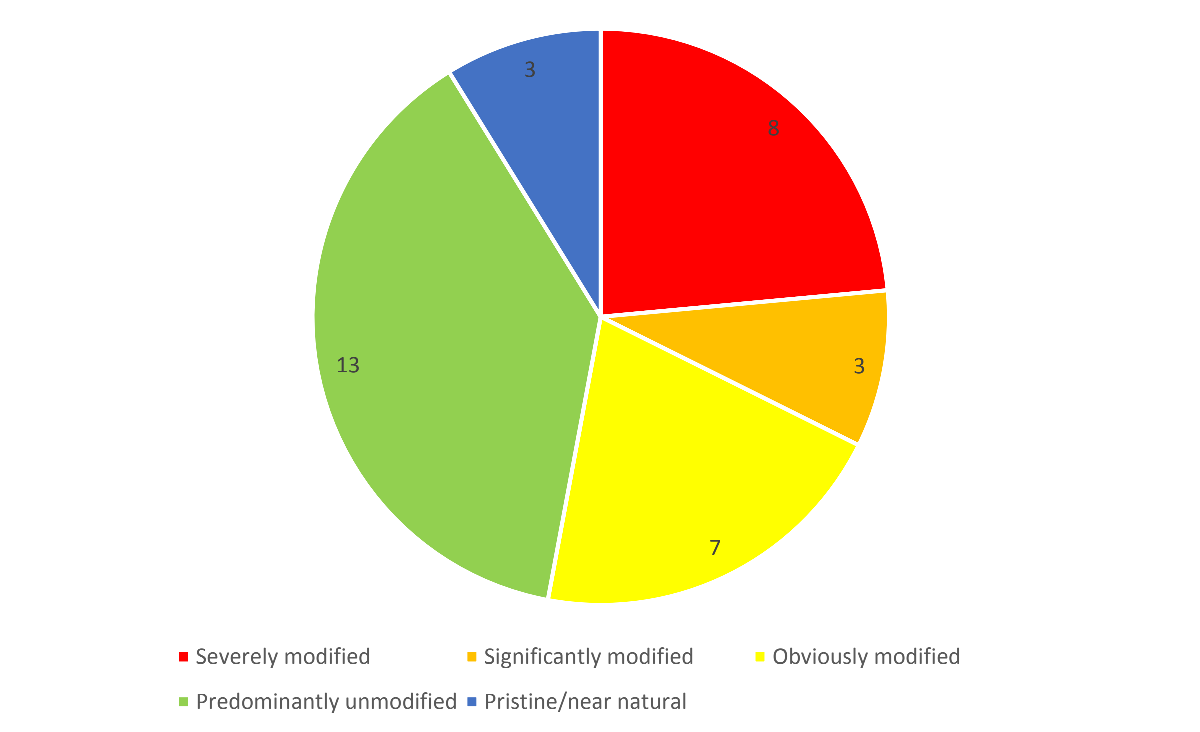

Figure 8.5.6.5 *Number of headwater sites in each habitat modification class in GMEP*

8.6 Long term trends

Data were obtained from NRW for all their macroinvertebrate samples from 1990 onwards, and screened to include only smaller headwater streams.

Three key indicators of ecological quality derived from macroinvertebrate communities were plotted against time (Figure 8.6.1), the BMWP score and its Ntaxa and ASPT. The BMWP score is an index of eutrophication and general degradation, Ntaxa is the number of water quality sensitive taxa that contribute to the BMWP score and ASPT is the sensitivity of the taxa to water quality which contribute to the BMWP score. The graphs show change in ecological quality over time with a decrease followed by an increase in the early to mid-2000s. The pattern was statistically significant for all 3 indicators. The overall pattern in BMWP score was driven by the ASPT rather than Ntaxa, so that there was over time species replacement by water quality sensitive species rather than just more species *per se*. This pattern is entirely consistent with that described by another study by Vaughan & Ormerod (2012) for England and Wales using a wider national dataset of which this is a subset restricted to Wales and to smaller streams. Our analyses demonstrates that patterns for Welsh headwaters are on par with the national UK trend.

Vaughan & Ormerod cited changes in water chemistry as the main reason for this trend, principally reflecting decreases in organic pollution over several decades. Patterns for the ecological indicators do appear to be inversely related to changes in N concentrations in stream water, as can be seen from NRW time series (Figure 8.6.2)(the sampling locations used were matched to the invertebrate sampling locations). However patterns in P matched ecological indicators only weakly (except perhaps for Ntaxa), although lags in the response of the ecology to the chemistry may be responsible for the lack of patterns.

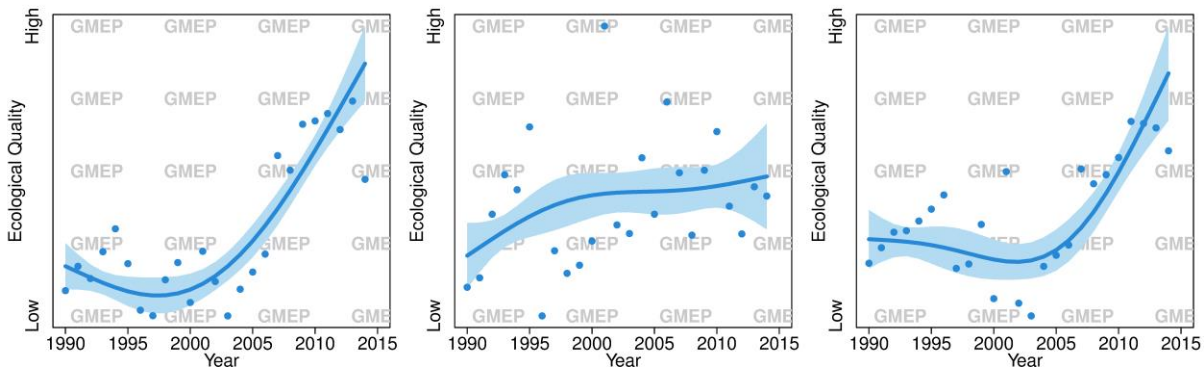

Figure 8.6.1 *BMWP score (left; an index of eutrophication and general degradation), Ntaxa (middle; the number of water quality sensitive taxa that contribute to the WHPT score) and ASPT (right; the sensitivity of the taxa to water quality which contribute to the WHPT score) time series derived from NRW data for Small Welsh streams.*

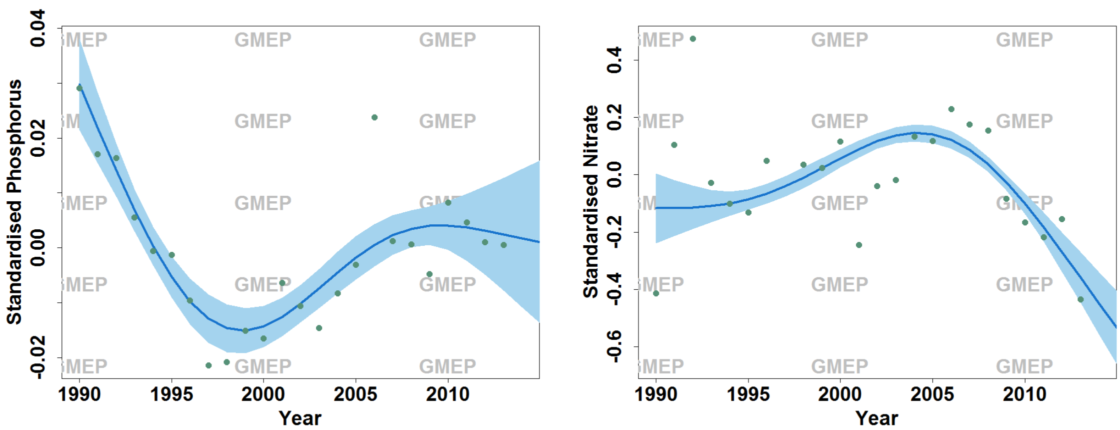

Figure 8.6.2 *Time series of left: SRP (mg/L) and right: TDN (ppm) derived from NRW monitoring*

8.6.1 Quality of headwater stream conditions in and out of the Glastir scheme

Main indicators were compared according to whether site was in or out of Glastir, and the relationship between indicator and % of upstream catchment in Glastir was analysed using regression methods (Table 8.6.1.1) No significant relationships were found based on the limited sample size of first year data, but the analysis will be repeated as survey years are added.

Variable	P Value	Outside Glastir		In Glastir	
		Mean	Std Error	Mean	Std Error
O/E ASPT	0.37	0.97	0.03	0.98	0.02
O/E Ntaxa	0.35	0.75	0.06	0.92	0.06
HMS	0.89	395.27	134.79	976.61	289.91
HQA	0.75	56.20	2.35	51.78	3.65
O/E TDI	0.56	0.95	0.07	0.91	0.04
TDN (ppm)	0.60	1.19	0.27	1.58	0.38
PO4P (mg/L)	0.27	0.03	0.01	0.01	0.01
O/E PO4P	0.32	1.71	0.60	1.35	0.55

Table 8.6.1.1 *Mean principal indicators of ecological quality according to sites that fall in or out of Glastir. P values indicate significance of a regression of indicator vs % of upstream catchment that is in Glastir, in this case none of the relationships are significant ($p > 0.05$).*

8.6.2 Influence of past agri-environment schemes (Tir Gofal)

We examined the influence of past AES on the ecological quality of survey sites using the main macroinvertebrate indicators linked to water quality (as most AES focus on nutrient levels, though it is worth noting that nutrients are only one component of chemical quality) (Table 8.6.2.1). Although there was a consistent pattern for higher indicator values in sites under past AES schemes, error terms were large so means did not differ significantly between sites falling in or out of previous AES.

	Status	Mean	SE
Ntaxa	Outside Past AES	16.44	2.06
	In Past AES	19.19	0.98
ASPT	Outside Past AES	5.66	0.28
	In Past AES	5.83	0.14
BMWP	Outside Past AES	93.44	11.69
	In Past AES	110.12	7.17

Table 8.6.2.1 *mean values of three main macroinvertebrate indicators of ecological quality in survey sites falling in or out of previous AES*

8.7 Ponds
8.7.1 Introduction

Ponds are more abundant than rivers and lakes, and are found in virtually all environments. Though the diversity of an individual pond will generally be less than that of a river or lake, their biodiversity value lies at wider spatial scales. At the landscape level ponds typically support a wide array of species (Céréghino et al. 2008, Williams et al. 2004), and are a particularly important habitat for rare and protected species. In Wales, this includes many species which are declining internationally such as yellow centaury and three-lobed crowfoot, as well as European protected species including great crested newt and floating water-plantain. In addition, ponds provide both habitat and food for terrestrial wildlife such as birds, bats, small mammals, reptiles, and pollinating insects, making them important in agricultural and urban landscapes that have few natural refugia. Ponds, are recognised in Article 10 of the EU Habitats Directive for their role as 'stepping stones', between other waterbodies and wetlands, increasing freshwater habitat connectivity at wide spatial scales. Ponds also act as small reservoirs as they collect and slow the flow of water off fields and other areas, trapping and recycling nutrients and sediments before they can enter a flowing water body.
Ponds have been widely lost through urbanisation and intensification of agriculture, and their numbers declined greatly during the 20th century (Nicolet et al. 2007). Ponds, like headwater streams, are vulnerable habitats that experience the common pressures which affect all freshwater habitats, but they are also exposed to localised pressures. Due to their small size, compared to a river or lake, they are particularly sensitive to pollution and have a limited buffering capacity (Williams et al. 2004), similar to headwater streams. In agricultural landscapes ponds receive sediments, nutrients and pesticides which has direct effects on the biota and habitat integrity, for example decreasing biodiversity and causing a replacement of sensitive fauna by pollution tolerant types.

Five ponds types are included partly or wholly as habitats of high conservation importance in Annex 1 of the EU Habitats Directive (H3160, H3170, H3180, H3110, H3140), with another habitat types potentially including ponds (H3130) although few ponds have been designated as Special Areas of Conservation in their own right. The Water Framework Directive protects all surface waters, though in practice, in the UK a minimum size limit of 50 ha is applied to water bodies (5 ha in SAC's) that are subject to monitoring thus excluding ponds (usually designed as <2ha). The most relevant policy to ponds is perhaps the UK Biodiversity Action Plan which designates high quality ponds as Priority Habitat (based on a number of criteria), and confers them some protection. Hence it is not surprising that ponds are a target of many agri-environment schemes, including Glastir, with options that aim to reduce run off, increase ecological buffering and create new habitats.

8.7.2 Condition of ponds

Ponds were monitored in 60 x GMEP 1km survey square across Wales in 2013, with 1 pond in each square (if present) selected for detailed surveying (the pond most central to the square was used if more than one pond was present).

Of the 60 GMEP 1km survey squares surveyed, 48% (29) had at least one pond. In total 99 ponds were recorded over the 60 GMEP 1km survey squares with 28% (17) of the squares having more than 1 pond (between 2 and 7). Of the GMEP 1km survey squares with ponds approximately half had only ponds, and half had both ponds and headwater streams.
Pond area was recorded for 52 ponds of the 99 ponds averaging 305 m^2 (±56). Only 3 ponds were judged to have been created recently (less than 5 years).

8.7.2.1 Water chemistry

The results of the water chemistry sample analysis (Table 8.7.2.4.1) are harder to interpret for ponds than for streams, because of the inherent variability that arises from the diverse nature of ponds and their surroundings. All chemical determinands had a higher mean for lowland sites than for upland sites, however differences between upland and lowland sites were not statistically significant for most determinands, which all displayed wide value ranges, including nutrients (Figure 8.7.2.4.1). Only alkalinity was significantly higher in lowland vs upland, as would be expected from geology, and consistent with the chemistry of the headwater streams.

8.7.2.2 Macrophytes

Wetland plant species were surveyed in each pond and used to derive three pond quality metrics (Table 8.7.2.4.2). Contemporaneously collected environmental variables were run through the PSYM model (Freshwater Habitats Trust, 2015) to predict the pond quality metric values that would be expected if the pond was minimally impaired by human activity (i.e. in reference condition). The ratio of observed to predicted metrics (Table 8.7.2.4.3) or ecological quality ratio at each pond indicates the pond's quality, where a value of 0.75 or above indicates a plant assemblage in reference condition. Thresholds for the ratios, provided by the PSYM method, allowed each metric to be ranked into one of 4 categories (very poor, poor, moderate, and good).
Results for each of the three PSYM plant metrics are outlined below.

The Trophic Ranking Score (TRS) is a measure of the average trophic rank of ponds, and is based on the affinity of each plant to nutrient status of the water. In contrast to most metrics, which have a linear relationship with degradation (i.e. the higher the metric score the lower the degradation, or vice versa), Tropic Ranking Score has a U-shaped relationship with increasing degradation: where observed values that are significantly higher than expected this suggests degradation from nutrient enrichment, where observed values are lower than expected this suggests degradation through acidification. Amongst the GMEP ponds (Table 8.7.2.4.2) TRS was significantly higher in lowland sites than at upland sites, as well as its observed to expected ratio. Mean values of TRS O/E corresponded to poor ecological quality in lowland but good ecological quality in upland ponds.

The submerged and emergent species index (SM) is the number of submerged and emergent plant species recorded from the pond. The mean value did not differ significantly between lowland and

upland sites, albeit slightly higher in lowlands. The observed to expected ratio did not differ either between upland and lowland sites and was consistent with moderate ecological quality.
The uncommon species index (U) is the number of species with a rarity score of two or more. Values were always low, consisting of either 1 or 2 species. The mean of this index was significantly higher for upland sites, as was the ecological quality ratio, which corresponded to poor ecological quality. The mean was extremely low in lowland sites, corresponding to very poor ecological quality. Overall most uncommon plants (defined by FHT as having a rarity score of 2 or more, based on the occurrence of species in their data holdings) occurred in upland ponds, species included the rarer *Utricularia australis* as well as less rare species such as *Ranunculus omiophyllus*, *Riccia fluitans, Stellaria palustris, Glyceria declinata, Potamogeton obtusifolius, Lythrum portula, Hypericum elodes, Scutellaria minor, Callitriche platycarpa*.

An additional measure was also calculated: the percentage cover of emergents (%E), which is the percentage of the pond surface area that is overhung by emergent plants. This measure was significantly greater at lowland sites, which included ponds with 100% cover by emergent plants.

8.7.2.3 Macroinvertebrates

Invertebrate species were surveyed at each pond site using a standard biomonitoring technique (the national pond survey; Biggs et al, 1998). Three invertebrate-based pond quality metrics were calculated based on the invertebrate assemblage recorded (Table 8.7.2.4.4). Habitat variables recorded in the field, and the observed invertebrate metric values were used in the PSYM model (Freshwater Habitats Trust, 2015) as described above for macrophytes. Results for each of the three PSYM invertebrate metrics are outlined below. Observed values were then compared to the predicted/expected values as a ratio, as described above for macrophytes (Table 8.7.2.4.5). Thresholds for the ratios, provided by the PSYM method, allowed to rate each indicator in 4 categories (very poor, poor, moderate, good).

The average score per taxon (ASPT) is derived the same way as it is for streams, based on BMWP scores, and describes the sensitivity of species to water quality. It is an indicator of eutrophication, but is also considered an indicator of general degradation. Higher values indicate higher ecological quality. The ASPT did not differ between upland and lowland ponds, nor did the ratio observed to expected values. The mean observed to expected ratios were consistent with good ecological quality in lowland and upland.

The Odonata-Megaloptera index (OM) is the number of families of odonates (dragonflies and damselflies) and megalopterans (alder flies) at the site. These invertebrates are particularly sensitive to water quality and habitat quality. This indicator did not differ significantly between lowland and upland but was slightly higher in upland ponds. The observed to expected ratio did not differ either, despite also being higher in upland areas. The mean values of this indicator were consistent with poor quality in lowland and moderate quality in uplands. Four upland ponds and 3 lowland ponds had no Odonata/Megaloptera.

The Coleoptera (CO) index is the number of coleopteran families (beetles) recorded. This indicator is linked to both water quality and bank quality. Higher values indicate better ecological quality. The mean CO did not differ significantly between upland and lowland ponds, though it was higher in uplands. The observed to expected ratio did not differ significantly either but showed a similar pattern. The mean values of this indicator were consistent with moderate quality in lowland and good quality in uplands.

In addition to the PSYM metrics, we calculated two species richness indices: Margalef richness (Margalef, 1958) is a measure of richness corrected for the number of individuals (as the number of species increases passively with the number of individuals) and true richness (n) i.e. the number of recorded taxa (principally at species level though some taxa were recorded at higher levels of taxonomic organisation). Neither index differed significantly between upland and lowland though there were marginally more species in lowland areas.

We used the occurrence and abundance of macroinvertebrates in the samples to produce an ordination graph using canonical correlation analysis (CCA) as described in the headwater streams section. This technique explain patterns in variation in the community using selected environmental variables. We used a range of variables and tested their contribution to the CCA model using permutation tests. This indicated that, pond area, water pH, nitrogen, conductivity and the percentage cover of emergent plants did not contribute significantly to the model, but retained phosphate, alkalinity and altitude as significant explanatory variables. The model was plotted in an ordination, where the distance between samples is a measure of their ecological distance, and where the graph axes represent a combination of the driving variables, which are plotted as vectors, the length of which is an indicator of the influence of the variable (Figure 8.7.2.4.2). The graph suggests that altitude is the principal driver of differences in macroinvertebrate assemblages. There was a lesser effect from another natural variable: alkalinity, which in part co-varied with altitude but also accounted for some of the variability in itself. Phosphate was the second strongest driver after alkalinity and explained the majority of variability along the horizontal axis. Phosphate levels do vary naturally in ponds, but this nutrient is also strongly related to anthropogenic impacts, and together with the plant Tropic Ranking Score results (above), suggests that nutrient pollution may be impacting both plant and invertebrate communities in some of the ponds.

8.7.2.4 Ecological quality

The PSYM model sums the value from all six plant and invertebrate metrics to produce an overall index of biological integrity that summarises the ecological quality of the pond. The pond can then be classified according to thresholds in the overall index into four categories: very poor, poor, moderate or good, where good is equivalent to the high quality reference condition (Figure 8.7.2.4.3). Because PSYM score is one of the criteria used to identify Priority Ponds (a term used by FHT that is not related to ‘pond priority habitat’ under EU and UKBAP regulation), any pond that classifies as good quality, automatically qualifies as a Priority Pond. Amongst the GMEP ponds, the vast majority of sites fell in the *moderate* quality class, as for headwater streams. Two sites (8%) were classified as good, both situated in upland areas. Two sites (8%) were classified as very poor, also both in upland areas.

		Mean	SE	Min	Max
Alkalinity (mg/L)	Overall	51	15.4	-1.2	290.0
	Lowland (<200 m) *	94.6	29.1	4.4	290.0
	Upland (>200m)	16.7	7.67	-1.2	104.0
Phosphate (PO4-P) (mg/L)	Overall	0.09	0.03	0.01	0.36
	Lowland (<200 m)	0.10	0.04	0.01	0.36
	Upland (>200m)	0.07	0.03	0.01	0.14
Nitrogen (TDN) (ppm)	Overall	2.05	0.65	0.22	13.50
	Lowland (<200 m)	3.21	1.37	0.41	13.50
	Upland (>200m)	1.13	0.34	0.22	4.48
pH	Overall	5.78	0.16	4.07	7.19
	Lowland (<200 m)	5.99	0.18	5.18	6.70
	Upland (>200m)	5.62	0.25	4.07	7.19
Conductivity (µS.cm^{-1})	Overall	226.6	39.0	22.0	779.0
	Lowland (<200 m)	304.5	72.5	42.0	779.0
	Upland (>200m)	165.4	34.6	22.0	448.0

Table 8.7.2.4.1 *Water chemistry of GMEP ponds. Asterisks indicate where one altitude category is significantly higher than the other.*

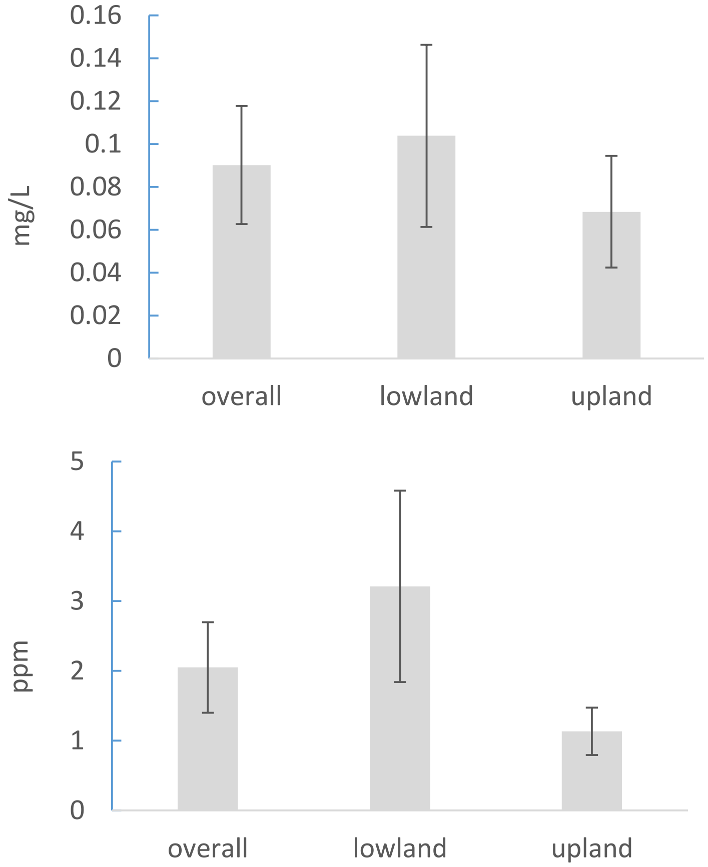

Figure 8.7.2.4.1 *Concentration of nutrients in pond water samples. Top: phosphate: PO4P (mg/L) and bottom nitrogen: TDN (ppm).*

		Mean	SE	Min	Max
Trophic Ranking Score (TRS)	Overall	7.3	0.56	2.5	10.0
	Lowland (<200 m) *	9.1	0.21	8.1	10.0
	Upland (>200m)	6.2	0.74	2.5	10.0
Number of submerged and marginal species (SM)	Overall	10.62	1.21	1.00	23.00
	Lowland (<200 m)	13.00	2.3	4.00	23.00
	Upland (>200m)	11.2	1.48	3.00	21.00
Number of uncommon plant species (U)	Overall	0.62	0.15	0.00	2.00
	Lowland (<200 m)	0.25	0.16	0.00	1.00
	Upland (>200m) *	1.00	0.21	0.00	2.00
E (%)	Overall	33.16	5.67	1.00	100.00
	Lowland (<200 m)*	47.73	9.83	1.00	100.00
	Upland (>200m)	21.71	4.97	1.00	65.00

Table 8.7.2.4.2 *Macrophyte indicators of ecological quality. Asterisks indicate where one altitude category is significantly higher than the other. Data from 29 ponds.*

		Mean	SE	Min	Max
O/E Trophic Ranking Score (TRS)	Overall	1.2	0.08	0.45	1.73
	Lowland (<200 m) *	1.43	0.08	1.06	1.73
	Upland (>200m)	1.01	0.11	0.45	1.73
O/E Number of submerged and marginal species (SM)	Overall	0.73	0.07	0.23	1.32
	Lowland (<200 m)	0.72	0.11	0.34	1.32
	Upland (>200m)	0.74	0.10	0.23	1.27
O/E Number of uncommon plant species (U)	Overall	0.21	0.05	0.00	0.72
	Lowland (<200 m)	0.06	0.04	0.00	0.26
	Upland (>200m) *	0.29	0.06	0.00	0.72

Table 8.7.2.4.3 *Ratio of observed mean to expected means using predictions of PSYM model. Data from 29 ponds.*

		Mean	SE	Min	Max
Average Score per Taxon (ASPT, BMWP)	Overall	4.64	0.11	3.50	5.89
	Lowland (<200m)	4.51	0.21	3.50	5.89
	Upland (>200m)	4.74	0.12	4.00	5.64
Number of dragonflies and alderfly families (OM)	Overall	1.62	0.27	0.00	4.00
	Lowland (<200m)	1.18	0.30	0.00	3.00
	Upland (>200m)	1.93	0.41	0.00	4.00
Number of water beetle families (CO)	Overall	2.81	0.22	1.00	5.00
	Lowland (<200m)	2.64	0.28	1.00	4.00
	Upland (>200m)	2.93	0.32	1.00	5.00
Richness (Margalef)	Overall	5.09	0.39	0.65	8.31
	Lowland (<200m)	5.21	0.46	3.24	8.06
	Upland (>200m)	5.00	0.60	0.65	8.31
Richness	Overall	37.85	3.38	4	65
	Lowland (<200m)	38.45	3.79	21	63
	Upland (>200m)	37.40	5.27	4	65

Table 8.7.2.4.4 *Macroinvertebrate indicators of ecological quality. Asterisks indicate where one altitude category is significantly higher than the other. Data from 29 ponds.*

		Mean	SE	Min	Max
O/E Average Score per Taxon (ASPT, BMWP)	Overall	0.86	0.02	0.65	1.16
	Lowland (<200 m)	0.87	0.04	0.65	1.16
	Upland (>200m)	0.86	0.02	0.70	1.02
O/E Number of dragonflies and alderfly families (OM)	Overall	0.56	0.09	0.00	1.60
	Lowland (<200 m)	0.42	0.10	0.00	0.99
	Upland (>200m)	0.67	0.14	0.00	1.60
O/E Number of water beetle families (CO)	Overall	0.78	0.06	0.65	1.16
	Lowland (<200 m)	0.69	0.07	0.27	1.04
	Upland (>200m)	0.84	0.09	0.28	1.37

Table 8.7.2.4.5 *Observed vs Expected ratio (O/E) of the three main macroinvertebrate indicators used in PSYM. Data from 29 ponds.*

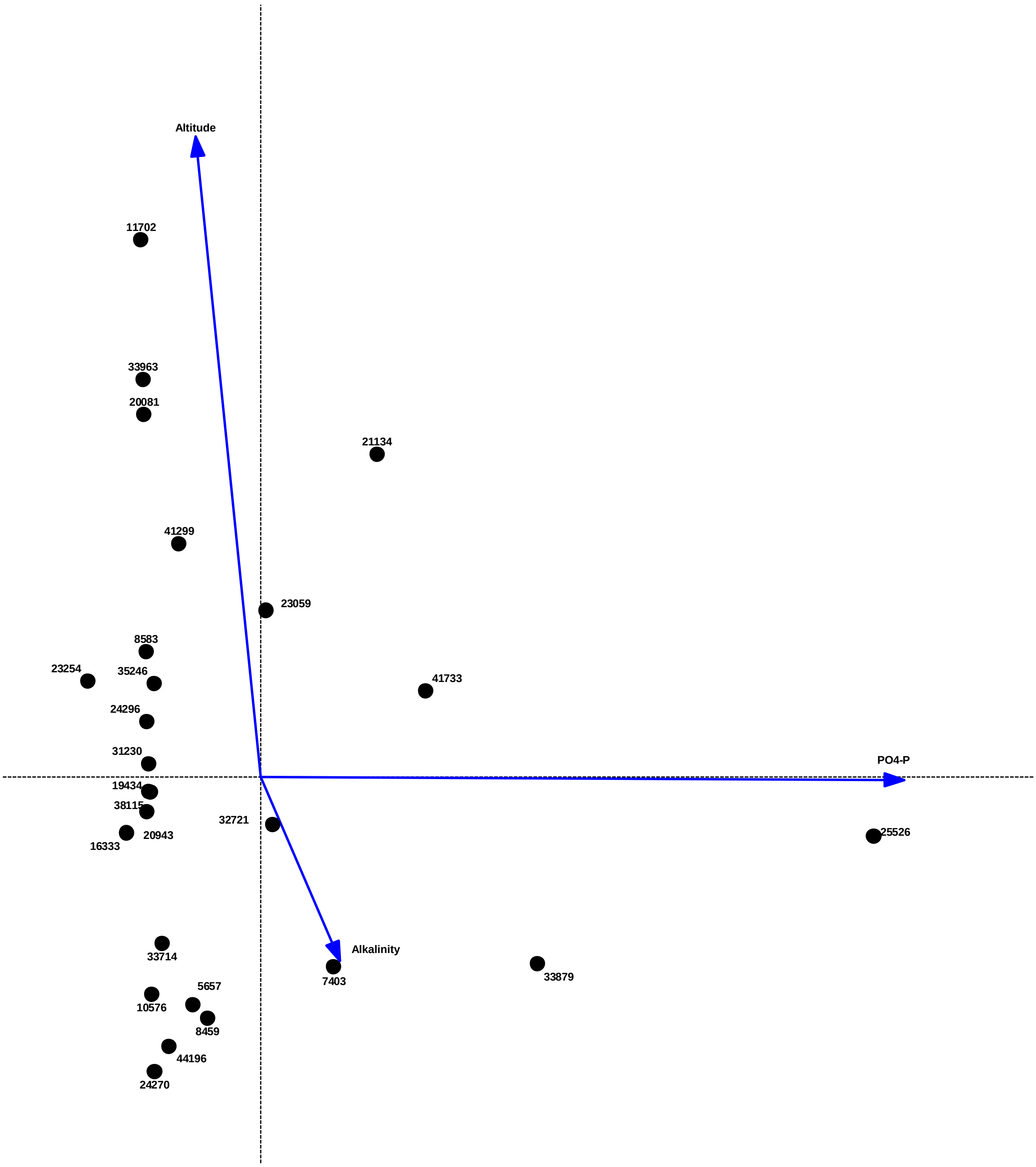

Figure 8.7.2.4.2 *CCA graph of pond macroinvertebrate community data with retained driving variables.*

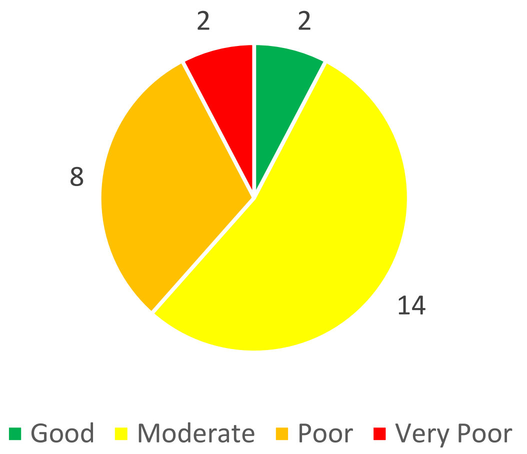

Figure 8.7.2.4.3 *Ecological quality of ponds in GMEP survey: number of ponds in each quality band*

8.7.2.5 Condition of ponds on land in and out of Glastir

We calculated mean values for the pond quality metrics (the ones for which reference values can be predicted by PSYM) for ponds falling in and outside of the Glastir scheme (Table 8.7.2.5.1; Figure 8.7.2.5.1). Three of the six metrics showed a significant difference in their means: the number of uncommon macrophytes (U), the number of water beetle families (CO) and the number of dragonfly and alderfly families (OM), which were all higher for sites falling in the Glastir scheme. Error terms indicated these differences were not statistically significant. Although the number of sites in the analysis was small 14 sites in Glastir, 15 not in in Glastir), the consistent trend in three of the six metrics are suggestive of a higher quality of ponds on land in Glastir.

We also analysed the response of the metrics to the percentage of the GMEP 1km survey square under Glastir. No significant relationships were found for any of the indicators, but a general positive trend was observed for all indicators (Figure 8.7.2.5.2), which may prove significant with the addition of more sites to the dataset each year.

	Status	Mean	SE
TRS	Outside Glastir	4.31	0.31
	In Glastir	4.67	0.12
SM	Outside Glastir	7.00	3.00
	In Glastir	10.92	1.28
U	Outside Glastir	0.00	0.00
	In Glastir	0.67	0.16
ASPT (BMWP)	Outside Glastir	4.31	0.31
	In Glastir	4.67	0.12
CO	Outside Glastir	1.50	0.50
	In Glastir	2.92	0.22
OM	Outside Glastir	0.00	0.00
	In Glastir	1.75	0.28

Table 8.7.2.5.1 *Mean values of 6 indicators according to whether the sites are in or out of Glastir*

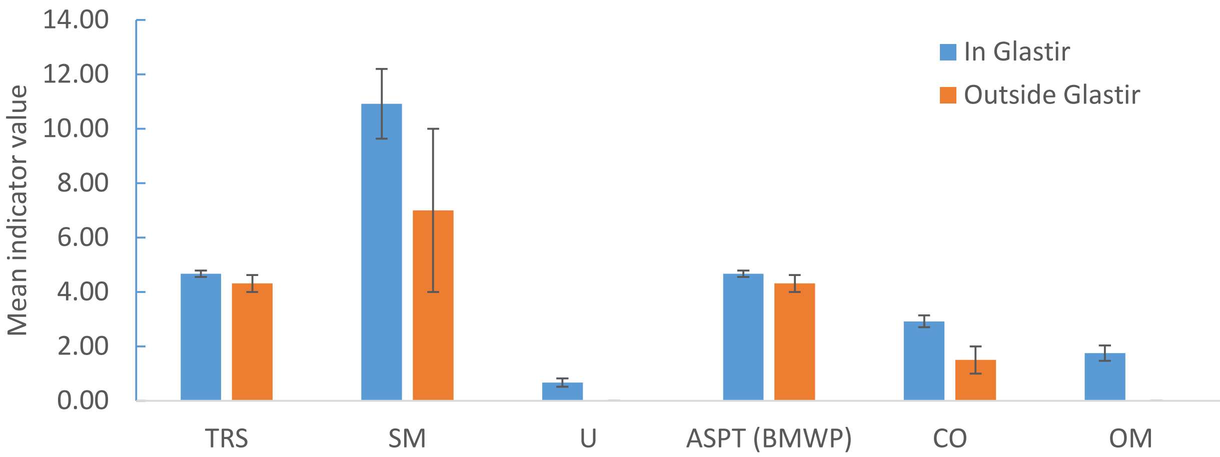

Figure 8.7.2.5.1 *Mean ± 1SE of each indicator for sites in and outside Glastir scheme*

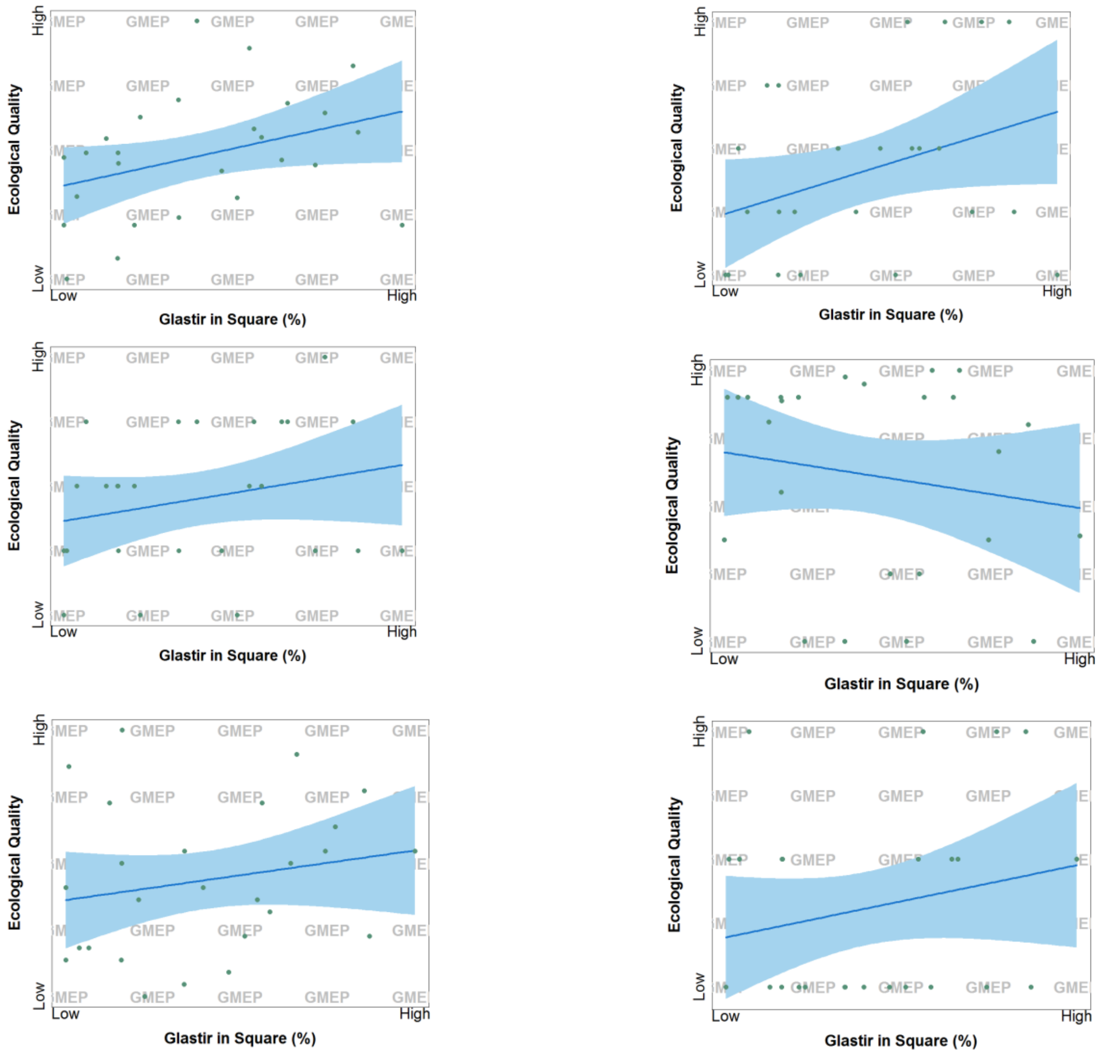

Figure 8.7.2.5.2 *Relationship between indicators of pond ecological quality and percentage of GMEP 1km survey square in Glastir. Left: macroinvertebrates, top: ASPT, middle: CO, bottom: OM. Right: macrophytes, top: SM, middle: TRS, bottom: U. n = 29*

8.8 Plans for year 3

Monitoring of headwater and ponds will continue in years 3 and 4 to complete the baseline survey subject to resources being available. The data will be analysed with respect to area of land in scheme, and with respect to ongoing trends as identified in the Wider Wales GMEP 1km survey squares. For streams this will include all land which contributes to the land upstream beyond the confines of the GMEP 1km survey square. For ponds it may be down-scaled to below GMEP 1km survey square level if the data is available. GMEP and NRW will work together to produce an assessment framework for headwater streams from the survey data, which will be consistent with WFD reporting. Data analysis will also be included in an integrated assessment of the data to identify trade-offs and co-benefits between different ecosystem elements and Glastir Outcomes i.e. combined analysis of the data from the vegetation, soil and habitat mapping. The data is also already being used in the landscape perception work.